Advanced Materials and Process for Cost-Effective High-Power Ultracapacitor Modules

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Overview

- What is an Electrochemical Double Layer Capacitors(Ultracapacitor)?
- Maxwell's Goals Under NIST program
  - High Energy Design Goals
    - 10 Whr/kg
    - 3.5 volt operation
    - 3 kW/kg, 6 second discharge to half voltage
    - Cost reduced to less than $40 for Baseline cell size (630 ml)
  - High Frequency Cell Design
    - 45º phase angle at 200 Hz
    - Energy density of at least 2 J/g

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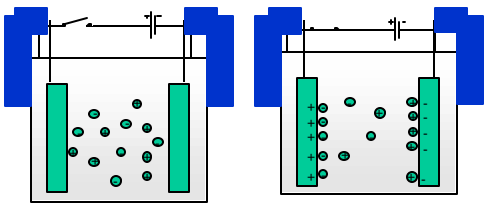
Overview(cont..)

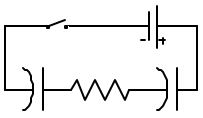
- Advanced Module Designs
  - Develop circuitry that provides ±100 mV control during applications requiring greater than 10% duty cycle at frequencies of greater than 0.01 Hz.
  - Minimize standby current of control circuitry to 2 mA for baseline size module.
  - Integration of advanced cell designs into a flexible module design. Six cell sizes of various capacities will be developed that can be easily configured to different energy, voltage and power levels.

Description of an EDLC

When an electric potential is applied between two electrodes immersed in an electrolytic solution, ionic species are absorbed on the conductor surface and are balanced by electronic charges in the electrode.



The system is analogous to two parallel plate capacitors. The charging is a highly reversible process, so the capacitor can be cycled over 500,000 times. An electrochemical capacitor has an order of magnitude higher energy than traditional capacitors and higher power than rechargeable batteries.



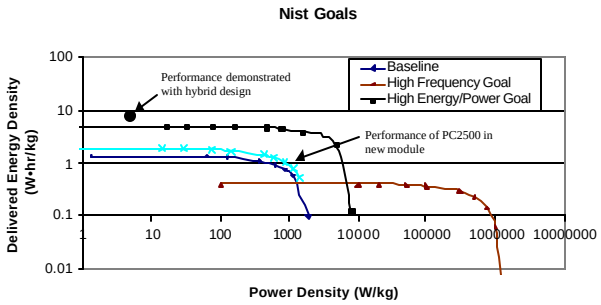
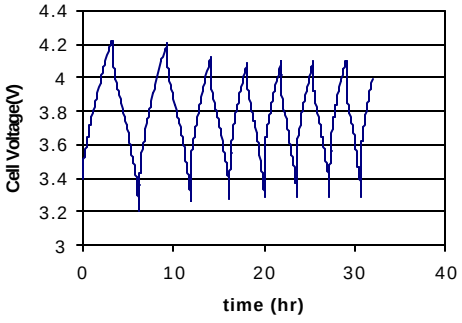


Figure : Charge and discharge behavior of a hybrid capacitor.



Cost Reduction

- Various electrolytes have been investigated. A new salt with higher performance and lesser cost has been identified
- A new paper separator with 1/6 Th the cost,with no performance degradation, has been identified
- Cheaper carbon electrodes has been identified

High Frequency Cell Design

- Thin electrodes with time constant lower than present design has been achieved
- The time constant has been reduced from 1sec to 0.5 sec.
- Efforts are underway to build commercial devices.

PowerCache Electrochemical Capacitors

- PowerCache capacitor
  - activated carbon double layer capacitor
  - composite fiber electrodes
  - aluminum added to increase conductivity
- High conductivity organic electrolytic solution minimizes resistance
- High power density
- Higher energy density than electrolytic capacitors
- Capacitance from a fraction of a farad to several kilo-farads

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PC2500 Performance Characteristics

Parameter	*Specification*	*Units*
Model	PC2500	
Case	Aluminum	
Electrode	Carbon	
Electrolyte	Organic	
Dimensions	161 x 62 x 62	mm
Weight	700	g
Volume	0.618	l
Rated capacitance	2700	F
Stored Energy (Float V)	7142	J
Specific Energy (Float V)	3	Wh/kg
Specific Energy (Surge at V)	4	Wh/kg
Maximum Float Voltage	2.3	V
Maximum Surge Voltage	2.7	V
Operating Temperature	-45 to 60	ºC
Storage Temperature	-45 to 85	ºC
Leakage Current	0.003	A
Series Resistance (25ºC)		
DC	0.85	mW
1kHz	0.5	mW

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Performance Characteristics, Cont..

Performance Characteristics

(Delivered)

Parameter	*Value*	*Unit*	
Specific Power			
Peak @ 2.7V	5316	W/Kg	
Peak @ 2.3V	3857	W/Kg	
6 seconds to ½ V	855	W/Kg	
60 seconds to ½ V	124	W/Kg	Assumes constant current discharge from 2.3V to1.15V
300 seconds to ½ V	26	W/Kg	
Discharge Energy			
@ 300 seconds	5302	J	
@ 60 seconds	5095	J	
@ 6 seconds	3517	J	
Energy Efficiency			
@ 300 seconds	99	%	
@ 60 seconds	98	%	
@ 6 seconds	83	%	

Efficiency = energy delivered/(energy delivered + lost) for constant current discharge.

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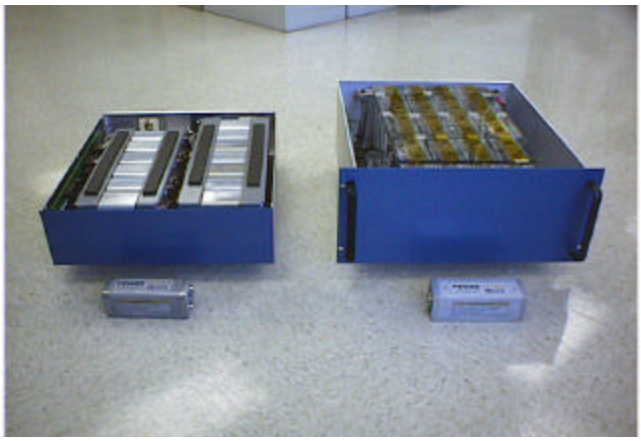
40% Volume Reduction of 56-Volt Bank



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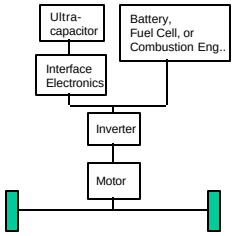
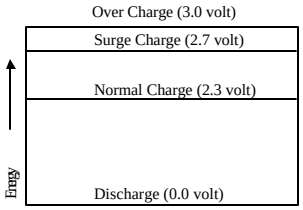
Ultracapacitors for Hybrid Vehicles

- Performance characteristics
  - High power density
    - power assist in HEV
    - regenerative braking
    - energy low for hill climbing
  - Long cycle life (>100,000)
  - Significant surge capability
  - Low cost base materials
  - Quick recharge
  - Easily monitored state of charge
  - No charge/discharge memory
  - High cycling efficiency
  - Excellent cold temperature performance
  - High reliability
  - High energy density relative to electrolytic capacitors

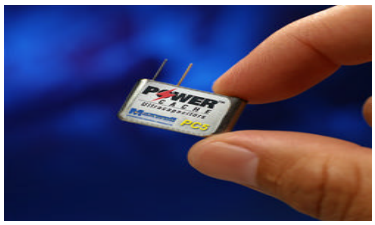




RTS100B-C Ride-Through-System

- For use with 100 kW ASD systems
- User selectable output voltage up to 650 volt
- Five second ride-through at 100 kW
- Eight 56 volt ultracapacitor modules
- Each 56 volt module equipped with 28 PC7223 PowerCache Ultracapacitors

4F, 250 m.ohm capacitor has been developed for communication need. This could be used either as a single unit or two in series in combination with battery.
For mobile phone applications, battery life has been doubled by using EDLC with the battery.



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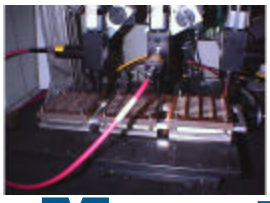
High speed automation line has been established



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Conclusions

- Cost effective materials has been found
- This helped us to reduce the cost of commercial capacitors
- Effective weight and volume of the capacitors were decreased
- Balancing circuits were developed to assemble banks of capacitors
- Both 56V and 650V systems were developed
- Small capacitors for mobile communication were developed
- Cost effective high speed manufacturing line is currently installed.

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